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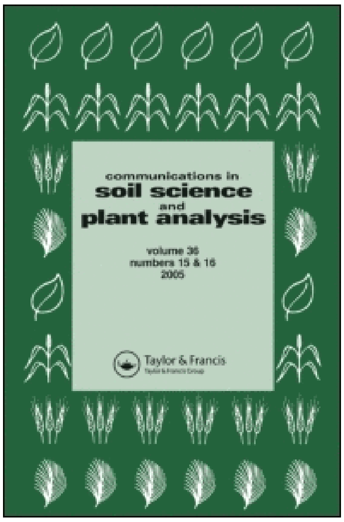

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RICE CULTIVAR RESPONSE TO ALUMINUM IN NUTRIENT SOLUTION

Key Words: Al toxicity, P uptake efficiency, Oryza sativa

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ABSTRACT

Aluminum toxicity is an important growth limiting factor for crop production on acid soils. The effect of five Al concentrations (0, 371, 742, 1484, and 2226 µM) in nutrient solution on the growth and chemical composition of six upland rice (*Oryza Sativa* L.) cultivars (IAC 1131, Fernandes, Matao, IPEACO 562, IRAT 2, and IPEACO 162) was studied. The concentrations and activities of Al species in the nutrient solution were calculated using the GEOCHEM program. The range in calculated activities of each of the Al monomers was 73 to 411 µM for Al^{3+}, 7 to 41 µM for $Al(OH)^{2+}$, 4 to 21 µM for $Al(OH)_2^+$, 0.07 to 0.41 µM for $Al(OH)_3^o$, and 125 to 495 µM for $AlSO_4^+$. Aluminum reduced shoot and root growth but the magnitude of the reduction varied from cultivar to cultivar. The cultivar Fernandes was most tolerant and IPEACO 562 most susceptible to Al toxicity of those cultivars tested relative to shoot dry weight. Fernandes also had high P uptake and low Al concentration in the shoot compared

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to the other five cultivars. The uptake and use efficiency of P was more highly correlated with the growth of rice than the uptake or use efficiency of Ca or Mg.

INTRODUCTION

Aluminum toxicity is a well-known limitation to crop production in acid soils in many parts of the world. The problem is particularly serious in strongly acid subsurface soil horizons (pH < 5.5) that are difficult to lime. Aluminum toxicity reduces growth of shoot and root, but many researchers have used root growth as the parameter to evaluate Al toxicity in crop plants[4,7]. The reduction of root growth may restrict absorption of water and nutrients and lead to yield reduction in low fertility soils. Aluminum toxicity is also responsible for inhibition of nutrient uptake[2,3].

The two most common ways to alleviate Al toxicity are by liming and by using tolerant cultivars. It is possible to detoxify Al in surface soil in the field by liming to a pH of about 5.5 or above. However, liming of subsoils is difficult and generally not economical. Under such situations, use of tolerant cultivars in combination with surface liming may be a satisfactory solution to this problem. Plant species and genotypes within species differ widely in tolerance to Al toxicities[1,4,5].

The objective of this investigation was to evaluate the influence of Al on growth and uptake of nutrients by six upland rice cultivars.

MATERIALS AND METHODS

An experiment was conducted in a greenhouse to study the influence of Al on growth and chemical composition of six rice cultivars.

Seeds of six rice (*Oryza sativa* L.) cultivars were germinated in pure sand using plastic trays of 30 X 45 X 8 cm. Eight to 10

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days after sowing, four uniform sized seedlings were transplanted to acrylic discs with holes in the center. The seedlings were held in place with cotton. These discs were transferred to plastic pots containing 7.5 liters of nutrient solution. Each pot had three discs with four plants per disc.

The solutions used to grow plants were based on that recommended by the International Rice Research Institute in the Philippines for rice. The composition of the nutrient solutions was in µM: NH_4NO_3 2857; $NaH_2PO_4 \cdot H_2O$ 129; K_2SO_4 1023; $CaCl_2$ 1000; $MgSO_4 \cdot 7H_2O$ 1645; $(NH_4)Mo_7O_{24} \cdot 4H_2O$ 0.5; $MnCl_2 \cdot 4H_2O$ 9; H_3BO_3 18.5; $ZnSO_4 \cdot 5H_2O$ 0.15; $CuSO_4$ 0.16; and $FeCl_3 \cdot 6H_2O$ 36. Aluminum in amounts required for Al concentrations of 0, 371, 742, 1484, and 2226 µM was added as $AlCl_3$. The activities of each of the Al monomeric species were calculated by the GEOCHEM[9] computer program using equilibrium constants reported by Lindsay[8].

The nutrient solutions were changed every seven days. The pH of the solution was adjusted to 4 $\pm$ 0.2 initially and every two days thereafter with 0.1 *N NaOH or* 0.1 N HCl. The experiment was conducted in a randomized block design with two replications. Maximum and minimum air temperature means during the experiment were 28 $\pm$ 2°C and 18 $\pm$ 2°C, respectively.

After 21 days growth in Al treated solutions, plant tops and roots were harvested. Roots were rinsed thoroughly in distilled water and blotted dry. Roots and tops were dried to a constant weight at 80°C. Plant analyses for Al, P, Ca and Mg was done simultaneously with a plasma emission spectrophotometer.

RESULTS AND DISCUSSION:

The calculated activities of Al monomers are presented in Table 1. The range in calculated activities of each of the Al monomers was 73 to 411 µM for Al^{3+}, 7 to 41 µM for $Al(OH)^{2+}$, 4 to 21 µM for $Al(OH)_2^{+}$, 0.07 to 0.41 µM for $Al(OH)_3^{\circ}$, and 125 to 495 µM for $AlSO_4^{+}$. The calculated values of Σ activities of monomeric Al species

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TABLE 1
Calculated Activities of Al Monomers in Nutrient Solution.

Conc. of Al Added	$a_{Al^{3+}}$	$a_{Al(OH)^{2+}}$	$a_{Al(OH)_2^+}$	$a_{Al(OH)_3^o}$	$a_{AlSO_4^+}$	Σa_{Almono}†	P/Al
			µM				
371	73	7	4	0.07	125	209	0.35
742	145	15	7	0.14	227	394	0.17
1484	279	28	14	0.28	384	705	0.09
2226	411	41	21	0.41	495	968	0.06

†$\Sigma a_{Almono} = \Sigma\ a_{Al^{3+}} + a_{Al(OH)^{2+}} + a_{Al(OH)_2^+} + a_{Al(OH)_3^o} + a_{AlSO_4^+}$.

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($\Sigma a_{Al\ mono}$) in nutrient solution varied from 209 to 968 µM as a result of varying concentration of Al at pH 4. The calculated activity of $AlSO_4^+$ was highest followed by Al^{3+} activity and the activity of $Al(OH)_3^o$ was the lowest at all added Al concentrations. Activity of total monomers increased with increasing Al levels in the nutrient solution while P/Al ratio decreased. Aluminum monomer activities were lower than the added amount of total Al.

Rice cultivars growth parameters as influenced by Al treatment are presented in Table 2.

The increasing Al concentrations decreased root and shoot dry weights and root lengths. Some Al tolerant cultivars such as Fernandes and IAC 1131, had a slight increase in growth at the lower Al level (371 µM). This indicates that a small amount of Al may be beneficial for some rice cultivars. Howeler and Cadavid[6] and Thawornwong and Diest[10] also reported that small amount of Al stimulate rice growth in nutrient solution. The mechanisms by which small quantities of Al benefit plant growth are not clear and may be different for different plant genotypes and growth media[5]. One explanation for the beneficial effect of Al may be improved nutrient uptake. It has

TABLE 2
Influence of Al on growth parameters and concentrations of Al, P, Ca and Mg in rice cultivar shoot.

Cultivar	Al Conc.	Root Dry Wt.	Shoot Dry Wt.	Root Length†	Al	P	Ca	Mg
	μm	---g/plant---		cm	μg g^{-1}	-μg g^{-1} X 10^{-2}-		
IAC 1131	0	0.80	3.43	21	100	50	27	39
	371	0.80	3.47	23	200	45	21	28
	742	0.69	3.23	18	300	41	18	27
	1484	0.44	1.55	16	1200	42	14	28
	2226	0.28	1.40	14	1300	37	12	20
LSD (P = 0.05)		0.09	0.49	1	185	3.2	6.9	6.1
Fernandes	0	0.75	2.82	21	100	84	21	33
	371	0.83	3.28	30	100	76	18	31
	742	0.82	2.78	20	100	61	16	22
	1484	0.81	2.84	18	200	58	15	21
	2226	0.59	1.94	17	900	62	14	19
LSD (P = 0.05)		0.12	0.22	0.22	182	8.1	9.9	4.3
Matao	0	0.69	3.55	21	100	51	17	34
	371	0.60	2.91	19	100	54	17	28
	742	0.54	2.60	19	100	54	16	28
	1484	0.46	1.99	18	700	56	14	21
	2226	0.27	1.04	13	1400	59	13	25
LSD (P = 0.05)		0.10	0.34	0.21	243	9.1	5.6	9.5
IPEACO 562	0	0.47	2.48	22	100	60	11	36
	371	0.40	1.63	23	200	44	18	24
	742	0.29	1.13	20	200	41	17	22
	1484	0.18	0.29	18	700	22	14	28
	2226	0.41	0.15	17	3100	11	14	21
LSD (P = 0.05)		0.04	0.22	0.13	244	8.3	16.8	9.2
IRAT 2	0	0.38	1.94	26	100	60	22	50
	371	0.35	1.16	26	200	39	22	32
	742	0.31	1.05	24	200	50	20	32
	1484	0.22	1.50	20	800	24	16	30
	2226	0.16	0.25	19	2200	13	13	34
LSD (P = 0.05)		0.05	0.23	0.37	229	11.0	9.3	10.2
IPEACO 162	0	0.33	1.85	25	100	67	22	36
	371	0.42	1.16	24	100	45	17	22
	742	0.20	0.64	23	300	51	18	28
	1484	0.14	0.23	19	900	16	15	28
	2226	0.15	0.45	11	3900	14	15	28
LSD (P = 0.05)		0.05	0.17	0.40	182	9.2	8.4	4.9

†Root length refers to the length of the longest root per plant.

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been reported by Fageria[3] that low levels of Al stimulated uptake of N, P, K, Ca, Mg, S, Fe, Cu, and Zn by Al tolerant EEA 304 rice in nutrient solution.

The overall mean of six cultivars showed a 41 to 44% reduction in root weight, 58 to 70% reduction in shoot weight and 19 to 37% reduction in root length at 1484 and 2226 µM Al. This indicates that shoot weight was more susceptible to Al toxicity than roots. If this is the case, then it is much easier for researchers to use shoot growth for screening rice genotypes for Al toxicity especially when soil is used as a growth medium. It is generally reported that root growth is more sensitive to Al toxicity than shoots; however, separation of roots from soil is a tedious and time consuming job.

Based upon the above results shoot weight was used as a parameter to classifying six rice cultivars for Al toxicity tolerances (Fig. 1). Rice cultivar susceptibility to Al toxicity was Fernandes < IAC 1131 < Matao < IPEACO 162 < IRAT 2 < IPEACO 562. Fernandes was the most tolerant and IPEACO 562 most susceptible to Al toxicity.

The calculated activities of Al^{3+} in nutrient solution associated with a 50% reduction in shoot growth were: IPEACO 562 and IRAT 2, 100 µM; IPEACO 162, 172 µM; Matao, 300 µM; IAC 1131, 340 µM; and Fernandes, >400 µM. The cultivar Fernandes had a consistently high tolerance to Al toxicity compared to the other five cultivars.

Concentration of Al, P, Ca and Mg in shoots of plants grown with varied levels of Al are presented in Table 2. Aluminum concentration in shoot, increased with increasing Al concentrations in the nutrient solution, as expected. At the higher Al levels, Fernandes (the most tolerant cultivar) had lower concentrations in the shoots than the other five cultivars, at higher Al levels. At the higher levels of Al, P, Ca and Mg concentrations decreased in the shoots.

One interesting feature was that the Al tolerant cultivar Fernandes absorbed more P than the other five cultivars. The

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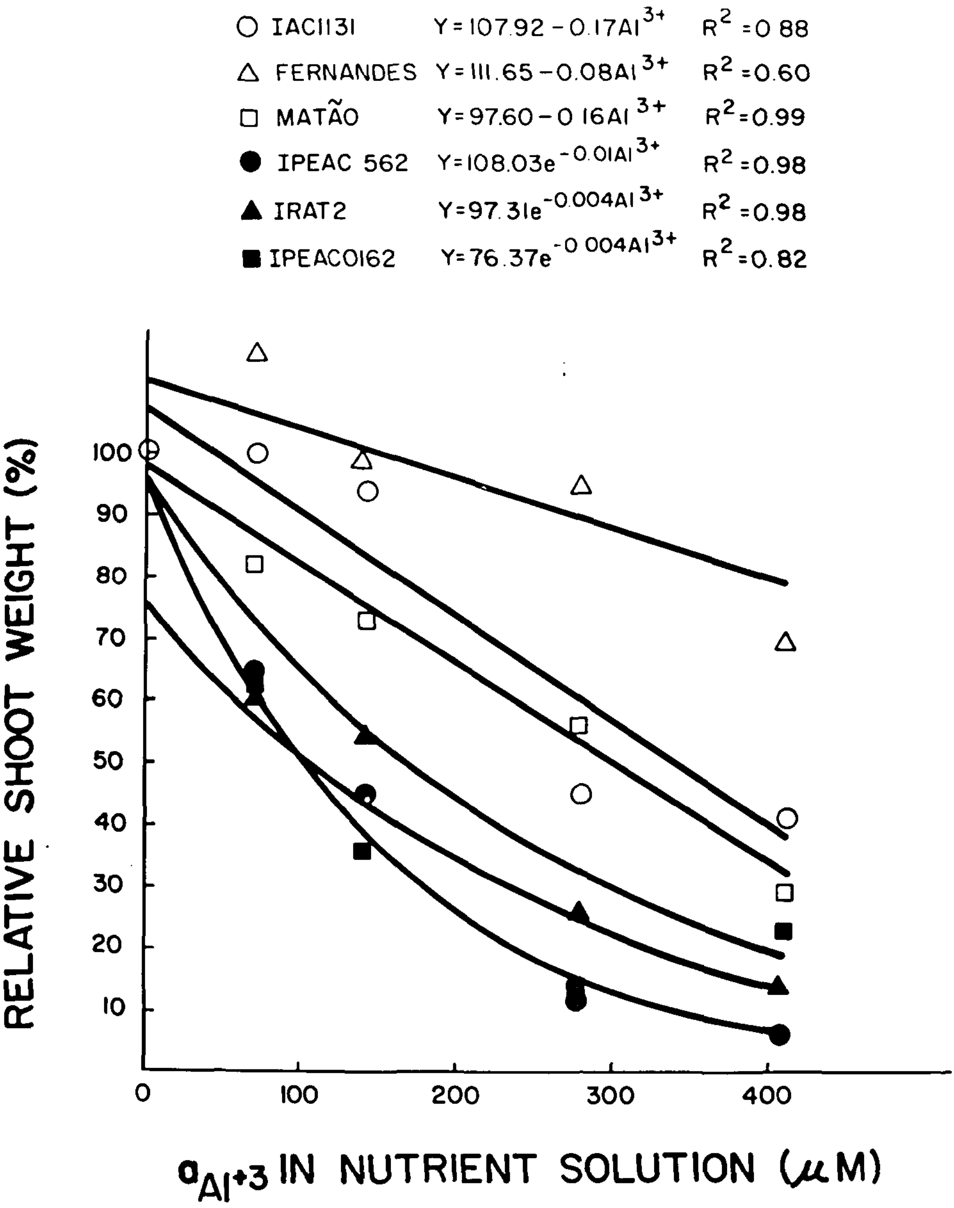

Fig. 1. Influence of $a_{Al}{}^{3+}$ on relative shoot growth of 6 rice cultivars.

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TABLE 3
Simple correlation coefficient between shoot and root growth and uptake, ER, Al monomer activities and treatment Al.

Variables	Shoot Dry Wt.	Root Dry Wt.	Root length
Uptake†			
P	0.94**	0.84**	0.36NS
Ca	0.94**	0.82**	0.36*
Mg	0.93**	0.74**	0.46**
Al	-0.05NS	0.05NS	-0.73**
ER‡			
P	-0.67**	-0.40**	-0.39*
Ca	-0.35NS	-0.31NS	-0.60**
Mg	-0.15NS	0.05NS	-0.49**
Al Speciation			
Al^{3+}	-0.60**	-0.37*	-0.77**
ΣAl mon	-0.60**	-0.37*	-0.76**
ΣAl mon-$Al(SO_4)_2^-$	-0.60**	-0.37*	-0.76**
Treat Al	-0.60**	-0.37*	-0.77**

NS = Not Significant, *, **Significant at the 5 and 1% levels of probability, respectively. ‡Efficiency ratio (ER) = mg dry shoot wt produced/mg of element absorbed. †Uptake = nutrient concentration x shoot dry wt.

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uptake and use efficiency (ER) of P was more highly correlated with dry weight production of rice than the uptake or use efficiency of Ca or Mg (Table 3). These results indicate that Al tolerance may be closely associated with P absorption efficiency in rice cultivars.

Similar relationships were observed between various Al monomer activities and growth (Table 3).

Multiple regression equations relating shoot and root growth with Al monomer activity and nutrient uptake are presented in Table 4. The variance of shoot weight (96%) was attributable to UP, UCa and ER-Ca; 82% of the variance of root weight was attributable to UP, UCa and ER-Mg, and 69% of the variance of

TABLE 4

Multiple regression equations relating overall shoot and root growth of rice cultivars with activities of Al monomers, uptake of P, Ca, or Al (UP, UCa, or UAl), and efficiency ratio.

Growth Parameter	Regression Equation	R^2
Shoot Wt.	$Y = -1.16 + 0.05\ UP + 0.38\ UCa + 0.002\ ER\text{-}Ca$	0.96**
Root Wt.	$Y = -0.13 + 0.01\ UP + 0.05\ UCa + 0.0008\ ER\ Mg$	0.82**
Root Length	$Y = 24.88 - 3.3\ UAl - 0.003\ ER\text{-}P - 0.010\ Al^{3+}$	0.69**

**Significant at the 1% level of probability.

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root length was related to UAl, ER-P and activity of Al^{3+}. This indicates that uptake of Al and activity of Al^{3+} strongly influence root length.

Conclusions

On the basis of results obtained the following conclusions were made:

1. Rice cultivars responded differently to Al treatments with respect to growth and nutrient uptake.
2. Shoot dry weight was affected more by Al toxicity than root weight or root length in 30 day old plants.
3. The cultivar Fernandes was most tolerant and IPEACO 562 was most susceptible to Al toxicity of the six cultivars tested.
4. Uptake of phosphorus was decreased more as compared to Ca and Mg under Al stress.

REFERENCES

1. Clark, R.B., 1977. Effects of aluminum on growth and mineral elements of Al tolerant and Al-intolerant corn. Plant and Soil. 47: 653-662.

2. Fageria, N.K. and Carvalho J.R.P., 1982. Influence of aluminum in nutrient solutions on chemical composition in upland rice cultivars. Plant and Soil 69: 31-44.

3. Fageria, N.K., 1985. Influence of aluminum in nutrient solutions on chemical composition in two rice cultivars at different growth stages. Plant and Soil. 85: 423-429.

4. Foy, C. D., Orellana, R.G. Schwartz, J.W., and Fleming, A.L., 1974. Response of sunflower genotypes of aluminum in acid soil and nutrient solution. Agron. J. 66: 293-296.

5. Foy, C.D., 1978. The physiology of metal toxicities in plants. Ann. Rev. Plant Physiol. 29: 511-566.

6. Howeler, R. and Cadavid, L.F., 1976. Screening of rice cultivars for tolerance to Al toxicity in nutrient solutions as compared with a field screening method. Agron. J. 68: 551-555.

7. Kinraide, T. B., Arnold, R.A., and Baligar, V.C., 1985. A rapid assay for aluminum phytotoxicity at submicromolar concentrations. Physiol. Plant. 65: 245-250.

8. Lindsay. W.L. 1979. Chemical equilibrium in soils. John Wiley and Sons, New York, NY.

9. Sposito, G. and Mattigod, S.V., 1980. GEOCHEM: A Computer Program for the calculation of chemical equilibrium in Soil Solution and other natural water systems. Kearney Foundation of Soil Science, University of California, Riverside.

10. Thawornwong, N. and Van Diest, A., 1974. Influence of high acidity and aluminum on the growth of lowland rice. Plant and Soil. 41: 141-159.

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